DOCUMENT RESUME

ED 222 173 IR 010 406

AUTHOR Evans, Richard W.
TITLE Designing Computer-Based Education for Effective Information Retrieval: A Cognitive Science Approach.
PUB DATE 10 Mar 82
NOTE 19p.

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Cognitive Processes; College Students; *Computer Assisted Instruction; Course Evaluation; Higher Education; Information Retrieval; *Instructional Design; Intermode Differences; *Memory; *Problem Solving; Statistics; Student Evaluation; Test Items; Test Use
IDENTIFIERS *Cognitive Research; *Problem Oriented Instruction

ABSTRACT

Questions related to the instructional design of computer-based educational systems were addressed in a study in which college psychology majors completed a computer-based course in statistics using instructional units developed to teach the desired knowledge within the context of situations to which the knowledge is relevant--a technique called problem-oriented instruction. A set of 16 instructional units was developed, and those units which followed problem-oriented instruction design guidelines began by introducing students to a problem, the solution of which was the topic of the unit. The units were constructed to guide students, through an interactive process, toward the solution of the problem. Approximately 36 students enrolled in the course. Evaluation of the instructional approach revealed that students preferred the computer-based system to workbooks and that a significant improvement occurred in student rates of retention over lecture- and workbook-based methods of presentation. It was concluded that the improvement in students' problem-solving ability stemmed from the fact that many lessons in the course followed a problem-oriented instruction format. A detailed discussion of the results and their implications is presented and a bibliography and three figures are included. (JL)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED222173

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION
CENTER (ERIC)

This document has been reproduced as received from the person or organization originating it.
Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

DESIGNING COMPUTER-BASED EDUCATION FOR EFFECTIVE INFORMATION RETRIEVAL: A COGNITIVE SCIENCE APPROACH

by

Richard W. Evans

IR010406

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY

Richard W. Evans

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

Designing Computer-Based Education for Effective Information Retrieval: A Cognitive Science Approach

Richard W. Evans, Ph.D.
The Learning Center
State University of New York College at
Farmingdale, New York 11735
March 10, 1982

As Cognitive Science comes increasingly to be applied to the design of Computer-Based Education, instructional design techniques which address a growing list of cognitive activities are being developed. Much of this endeavor addresses the question of improving student acquisition of knowledge (Resnick, 1980). Especially important in this area is the interactive feedback which the computer is capable of delivering. Computer-based Education is especially effective when student-computer interactions are designed to ensure that the intricate componential skills which comprise a given activity are identified and individually treated(Burton, 1980; Brown and Burton, 1978). Equally important to the acquisition of effective knowledge and skills is instructional design which ensures that the knowledge and skills acquired are readily accessed and retrieved from memory when needed. This is especially the case when tasks must be performed under time-pressure as in military or other emergency activities. It is to the question of instructional design of computer-based education to ensure efficient access and retrieval of relevant information that this paper is addressed.

Ensuring Access to Relevant Information: Problem-Oriented Instruction.

One of the most intensively studied areas in Cognitive Science is the structure and functioning of human memory. While a large body of facts and theory have resulted from work in this area, there is a recurring phenomonon which can be distilled to a primary principle of memory access relevant to the design of Computer-Based Education. This primary principle

is simply that human memory access is contextually controlled. Regardless of the level of processing (Craik & Lockhart, 1972) employed, information which is stored is best retrieved within the context of other information processed at the time of storage. This fact is clear from a number of examples in the literature. Mnemonic devices are one of the most spectacular means of improving access to and retrieval from memory; they succeed by providing a context for the stored items to be recalled - the subsequent regeneration of the device (e.g., a set of loci) accesses the stored items in a manner which is often surprisingly easy (Bower, 1970). These contexts can take on a variety of forms from single words (Tulving and Pearlstone, 1966), to entire verbal passages (Bransford and Johnson, 1973), to visual scenes (Shepard, 1967) and even environmental situations (Baddeley, 1976). The prevalence of this finding is reflected in the fact that most theoretical models of human memory are designed to account readily for the contextual (it is often called "associationistic") operation of memory (Norman, Rumelhart, et.al., 1975; Collins and Loftus, 1975; Anderson, 1976).

In order to ensure that computer-based education builds knowledge and skills which are stored in such a way as to be accessed and retrieved at appropriate times, it is necessary to design instructional units which will teach the desired knowledge and skills within the context of the situations to which that information is relevant. This approach to the design of computer-based education is here referred to as Problem-Oriented Instruction.

In Problem-Oriented Instruction, the information to be acquired is taught within the context of the situations to which that information is applicable. As a result, the contextual-sensitivity of human memory operation will ensure that when a situation is encountered which requires access and retrieval of that information, the situation will constitute a contextual "cue" which will access the appropriate stored information. The

study which follows applies this principle of human memory operation to the design of computer-based education of elementary statistics.

Method

Materials and Equipment: Sixteen instructional units of about 2 hours duration each were prepared for presentation on a DEC PDP 11-45 computer equipped with 12 VT-100 video terminals. The units were designed to present a full course in elementary statistics, covering the range of topics from simple elementary descriptive statistics to one-way analysis of variance. The CAI language employed was one developed specifically for the project and was very similar to PILOT. Use of graphics was frequent and employed DEC's basic graphics package. The approach taken in designing the individual units was one which gradually evolved, and the process is described more fully elsewhere (Evans, 1981). Large portions of many of the computer-based units were written following Problem-Oriented Instruction guidelines and thus were designed to enable students to readily access relevant information in solving statistical problems.

Units which followed this design procedure typically began by introducing students to a problem, the solution of which was the topic of the instructional unit. The student was then guided, through an interactive process, in working through a complete solution to the problem. These units consisted primarily (over 60%) of this initial problem solving procedure, with the remainder of the unit concerned with extensions of this basic procedure. Following is an example demonstrating this type of instructional procedure for the topic of variability. The fictitious example below employs a very cooperative and perceptive student.

- - - - - - - - - - - - - -

(Computer) Suppose for the moment that you are engaged to conduct a study examining the short-term effects of alcohol on memory. In one group (the Experimental Group), subjects drink an ounce of alcohol 30 minutes prior to engaging in your memory task. The second group of subjects (the Control Group), drinks an equal amount of water before taking the memory test. The memory test consists of a single 15-item

list of words. The results of the task for the two groups follows:

Subject #	1	2	3	4	5	6	7	8	9
Control Group:	10	8	10	9	11	12	11	9	10
Experimental Group:	14	6	13	7	8	12	10	8	12

Now study these results for a minute.
(hit "carriage return" to continue)

(Student) Hits Carriage Return.

(Computer) OK, now tell me - as the experimenter, would you conclude from these results that alcohol has no effect on memory?

(Student) "No". Hits Carriage Return.

(Computer) Oh? Well, let's see. Tell me this - do the means of the two groups differ from each other?

(Student) "No". Hits Carriage Return.

(Computer) Very good. You're right about that. So look, we have just found that the mean for these two groups is the same- doesn't that mean that alcohol had no effect on memory in your experiment?

(Student) "No". Hits Carriage Return.

(Computer) OK, so you think there is something in the results that shows a difference between the two groups which is not reflected in the mean?

(Student) "Yes". Hits Carriage Return.

(Computer) Very good. I think I agree with you. Shall we graph these results to get a slightly different look at them?

(Student) "Yes" Hits Carriage Return.

(Computer) OK, here they are.

Insert Figure 1 About Here

Tell me, do these graphs look correct to you (displaying both data and graph simultaneously).

(Student) "Yes" Hits Carriage Return.

(Computer) You're right, I've put no mistakes in these graphs. Let's examine them then. We know that the mean, or middle

point of each distribution is the same. But you suggested that there is some other difference between the two groups. Do you see that difference in these graphs?

(Student) "Yes". Hits Carriage Return.

(Computer) Would you say that the difference is reflected in how spread out the two groups are?

(Student) "Yes". Hits Carriage Return.

(Computer) I agree. There IS a difference between the two groups which the mean does not capture. In the case here, the subjects in group two are more different from each other than the subjects in group one. In other words they vary more from each other. Does it seem likely then, that the alcohol has affected memory by making it more variable?

(Student) "Yes". Hits Carriage Return.

(Computer) OK. Very Good. Now we need to figure out how to quantify these differences in variability.

- - - - - - - - - - - - - - -

The example above is simplified, but it serves to illustrate the main aspects of Problem-Oriented Instruction. Each of the necessary skills for dealing with the problem of variability is presented within the context of a situation in which the variability problem is encountered. First the student begins to learn the material within the context of a problem: there are two groups of subjects which appear to differ from each other, but their average performance is the same. Within this context, the student learns some procedures designed to ascertain the nature of the difference between the two groups - he can view graphs of their results, for example. As a result, the student is storing this information in memory within the context of the problem such that each of the principles useful in problem solution has been stored within the context to which it is relevant. Thus whenever he compares two

groups in the future, the student will process a contextual situation which should access and retrieve the procedure which checks variability between groups. Initiating such a check will in turn constitute the context which will access and retrieve the procedure for constructing and examining graphical representations of these results.

As the unit progresses, it will follow a similar approach, with the result that the student will have stored, within the context of the problem of comparing two groups of subjects, (and the embedded problem of finding differences in variability), procedures for deciding what numerical measure of variability is appropriate, and within that context, procedures for calculating the appropriate variability measure. As a result, it would be predicted that the student will subsequently be capable of solving such problems by quickly retrieving the relevant principles for problem solution.

Subjects: Subjects in the study were sophomore and junior psychology majors and minors enrolled in the Psychological Statistics course in the Psychology Department at Beaver College, Glenside, Pennsylvania. Approximately 36 students began the computer-based course. Another 23 students from the previous year's course participated in the evaluation.

Evaluation: Several different forms of evaluation were employed in assessing the effects of the computer-based course. As the computer was the only interactive form of instruction which the students had, there was no effect possible from lectures, though students had some contact with peer tutors when tested on the individual units. In general, then, any performance changes from previous years are likely to be due to the computer-based lessons. Students were administered rating scales for evaluation purposes at the conclusion of each unit mastery test and also at the conclusion of each semester. In addition, a check was made of retention rates (number of students enrolled over the duration of the course) and also rate of progress as measured by the calendar dates on which the corresponding unit tests were taken and passed. A final evaluation measure was a statistical problem solving test, designed by the author, to assess problem solving performance on ten different areas within elementary statistics. This test was presented in multiple-choice format both to students who had taken the computer-based course and to students who had previously taken the statistics course in Keller-method format.

Results

Student Evaluation: Analysis of the questionnaires revealed that the students significantly preferred the computer as a source of information to the workbooks available for study in the Keller method program. In addition, students found that the computer was as valuable in providing information as were the workbooks. (This aspect of the analysis is described more fully in Evans, 1981).

Retention Rates and Rates of Progress: Rates at which students dropped out of the Computer-Based and Keller-method courses were compared. Figure 2 reveals that these rates are comparable. The slopes of the regression lines, adjusted to reflect proportional class losses per instructional unit are .029 for the

computer-based course and .028 for the Keller method course.

Insert Figure 2 About Here

Examining the rate at which students progress through the two courses, figure 3 indicates that there is a rough parity. This is confirmed by the fact that the mean test completion day for the computer-based course is day 208.9, and for the Keller method course it is day 211.1.

Insert Figure 3 About Here

Statistical Problem Solving Ability: The Statistical Problem Solving Test was administered to students in the computer-based course and to students from the previous Keller-method course. Results on this 10-item test gave an average of 6.61 items correct for students taking the computer-based course, and an average of 4.64 items correct for students taking the Keller method course. A Student's t-test performed on the data yielded a t of 9.80 ($df = 46$, $p < .001$) indicating a highly significant improvement on problem solving ability for students in the computer-based course.

Discussion

The computer-based course had a highly significant effect in improving students' statistical problem solving ability. It is unlikely that the difference between the earlier Keller method course and the Computer-Based course is due to motivational factors: there was no effect on retention rates and rate of progress as a result of the computer. It is concluded, then, that the difference in problem solving ability stems from the fact that many of the instructional units in the computer-based course follow

a Problem-Oriented Instruction design format, and thus ensure that students are storing principles of statistical problem solution within the context of the problems to which those principles are relevant. As a result, these students, when confronted with a statistical problem, are able to access readily the information required to solve the problem.

A Closer Look:

It is possible to examine more closely the problem solving competency of the students from the two courses by making an item analysis of the Statistical Problem-Solving Test. Such an analysis has begun and allows the beginning of an examination of the efficacy of particular instructional sequences within the computer-based course. In turn this investigation will eventually permit some precise correlational analyses to be performed. The preliminary data allow a brief sketch of the conclusions which may eventually be forthcoming.

When the individual items in the Statistical Problem Solving Test are examined, it is clear that there are three areas of especial strength in the computer-based course. These areas are statistical power, Analysis of Variance, and hypothesis testing with two samples. While there are other areas of superiority for the computer-based course, these three are most pronounced. The problem area where there is the greatest difference between the computer-based and the Keller method courses is hypothesis testing. Here a comparison of performance on the test item devoted to hypothesis testing with two samples revealed a very highly significant difference in performance between the two groups ($z = 4.35$, $p < .00006$). The question testing problem solving ability in this area was designed to allow a separation of the various problem solving principles necessary to correct solution of the problem. By examining the incidence of correct use of these principles across the two groups of students, it can be

determined which of the principles has been taught in such a way as to promote efficient access and retrieval. This determination will allow a close examination of the corresponding instructional material to be made, and in turn allow a determination of the instructional design responsible for the development of such accessible stored knowledge and skills.

The item on the test which examined hypothesis testing with two samples was item (9). It read as follows:

---

9. A psychologist has a group of 10 subjects rate two television shows on a scale from 1 - 5 where 5 is the highest rating. The results are as follows.

Subject #	TV show # 1	TV show # 2
1	3	4
2	1	1
3	4	4
4	2	5
5	5	5
6	3	5
7	4	5
8	1	3
9	2	2
10	2	4

What statistical test would be appropriate here and also provide the most powerful test of these data?

a. independent samples t-test
b. related samples t-test
c. related samples sign test
d. two-way chi square
e. none of the above

By examining the pattern of responses on this item it is possible to determine which of the necessary solution principles have been successfully employed and accessed by the students in each group. Assuming that students who respond randomly or illogically distribute their responses equally across the possible answers, the following logic allows a determination of the principles which are successfully accessed and employed: Principle One

(of a total of three basic solution principles relevant here) requires that the student be aware that frequency data are treated by different statistical procedures than individual data which are recorded using a higher measurement (ordinal, integer or ratio) scale. In this case, the data are not frequency data, and the chi square test, which is designed for frequency data, can be eliminated from consideration. A student who answers (d) then, has failed to access and employ this first principle, and has also failed to apply principle three. The second principle requires recognition of the fact that statistical procedures which employ estimates of population parameters are not applicable to some measurement scales in which no such estimation is possible. In this case, the ordinal data of the rating scale used in this question does not allow the application of the t-test which is a parametric statistic. Thus a student answering either (a) or (b) has failed to access and employ this principle. Principle three involves use of the knowledge that sampling distributions for cases where samples are non-independent require adjustments in statistical procedures designed for independent samples. In this case the student who has successfully employed principles one and two, thus eliminating choices (d), (a), and (b) can decide that choice (c) does represent a viable solution, and allows the elimination of choice (e). Thus a student who answers (c) has correctly applied principles one, two and three. In addition, the student who answers (b) has correctly applied principles one and two but not three, and the student who answers (a) has correctly applied principle one but not principles two and three.

By examining the pattern of responses given to question number nine by the students in the computer-based and the Keller method statistics courses, it is clear that at least two of the solution principles are

accessed and employed by the students from the computer-based course at a much higher rate than that of the students from the Keller-method course. These principles are principles two and three: the principle regarding parametric statistics, and that regarding independence and non-independence of samples. The examination of the instructional design employed in teaching these two principles has only begun, and has concentrated on principle three, which shows the most dramatic improvement over the Keller-method course. Thus far, this preliminary investigation has supported the general contention of this paper: employment of Problem-Oriented Instruction in the design of computer-based education can promote the storage of knowledge and skills in a way which enables a relevant situation to access and retrieve this stored knowledge in an efficient manner. The sections of the computer-based course which covered principle three taught students the use of principle three within the context of the actual problems which they were likely to encounter at a later time.

Instructional Design to Promote Both Acquisition and Access: A Needed Synthesis: As stated at the beginning of this paper, much of the work in Computer-Based Education has focussed on the application of Cognitive Science to enhancing acquisition of knowledge and skills. This paper has emphasized that there also exists a need to design Computer-Based Education to ensure that such knowledge and skill is accessed and retrieved efficiently when the situations to which that information is relevant are encountered. The research discussed suggests very clearly that when computer-based education is designed following Problem-Oriented Instruction, the knowledge taught is accessed and employed appropriately. This design approach relies on the contextual sensitivity of memory

operation such that instruction of individual problem solving principles and skills are embedded within the "context" of the problems to which they are relevant.

It is necessary that further research be conducted on this question of designing Computer-Based Education to ensure access and retrieval of relevant information. This is necessary to elucidate the most effective procedures for ensuring access, and also to enable an integration of computer-based techniques designed to enhance acquisition with those designed to enhance access and retrieval of knowledge and skills. Such research should prove very fruitful as both aspects of computer-based education design appear to be highly effective, and it integration of the two may simply require interleaving acquisition and access techniques within the same instructional program.

References

Anderson, J.R., 1976, Language, Memory and Thought. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Baddeley, A.D., 1976, The Psychology of Memory. New York: Basic Books.

Bower, G.H., 1970, Analysis of a mnemonic device, American Scientist, 58: 496-510.

Bransford, J.D., and Johnson, M.K., 1973, Considerations of some problems of comprehension. In W.G. Chase (ed), Visual Information Processing. New York: Academic Press.

Brown, J.S. and Burton, R.B. Diagnostic models for procedural bugs in basic mathematical skills. Cognitive Science, 1978, 2, 155-192.

Burton, R.B. DEBUGGY: Diagnosis of errors in basic mathematical skills. In D.H. Sleeman and J.S. Brown (Eds) Intelligent Tutoring Systems, London: Academic Press, 1980.

Collins, A.M. and Loftus, E.F., 1975, A spreading-activation theory of semantic processing. Psychological Review 82:407-428.

Craik, F.I.M., and Lockhart, R.S., 1972, Levels of processing: a framework for memory research. Journal of Verbal Learning and Verbal Behavior. 11:671-684.

Evans, R.W., 1981, A Computerized course in elementary statistics: Educational objectives and methods. In Proceedings of NECC 1981: National Educational Computing Conference; p. 254-258.

Norman, D.A., and Rumelhart, and the LNR Research Group, 1975. Explorations in Cognition. San Francisco: Freeman.

Resnick, L., 1980, Instructional Psychology. Annual Review of Psychology, July 1980.

Shepard, R.N., 1967, Recognition memory for words, sentences and pictures. Journal of Verbal Learning and Verbal Behavior, 6: 156-163.

Tulving, E., and Pearlstone, A., 1966, Availability vs. accessibility of information available for words. Journal of Verbal Learning and Verbal Behavior. 5:381-91.

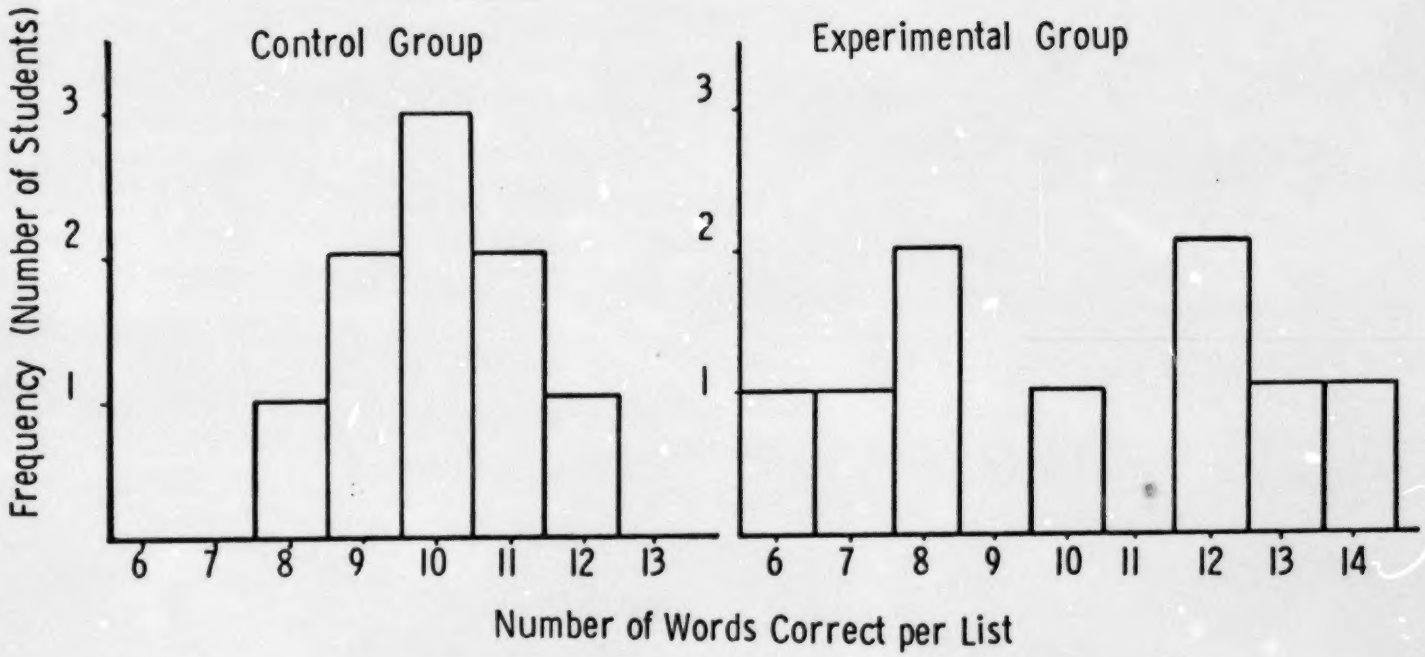
Control Group
Experimental Group
Frequency (Number of Students)
3
2
1
6 7 8 9 10 11 12 13
6 7 8 9 10 11 12 13 14
Number of Words Correct per List

Figure 2
Retention Rates for the Computer-Based and the Keller Method Statistics Courses

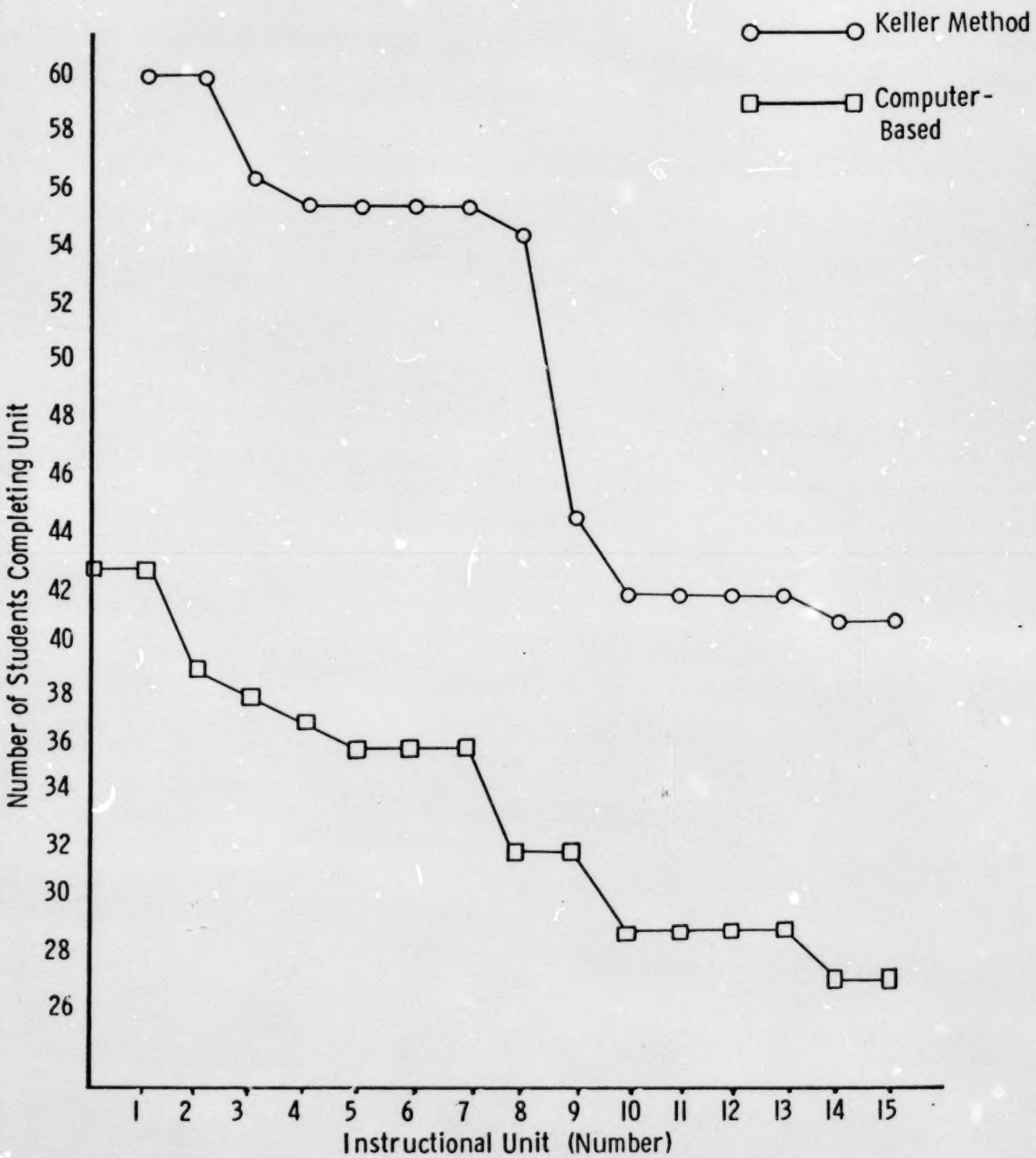

Figure 3
Progress Rates for the Computer-Based and the Keller Method Statistics Courses